FOREST RESEARCH REPORT

NOVA SCOTIA DEPARTMENT OF LANDS AND FORESTS
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WORKER PRODUCTIVITY IN MERCHANTABLE THINNING, SHELTERWOOD AND REMNANT REMOVAL OPERATIONS

INTRODUCTION

Over the past decade, silviculture activity in Nova Scotia has increased from an average of 10,000 hectares per year for the period 1976 - 1980 to approximately 45,000 hectares for the fiscal year 1987. Funds available under cost-shared federal-provincial agreements have provided much of the incentive for this increased activity on both private and crown lands. Under these agreements, landowners, contractors and companies receive full or partial payment up to a maximum rate for the completion of a variety of silviculture operations including tree planting, cleaning, remnant removal and merchantable thinning treatments. To provide a basis for refining silviculture treatment assistance rates, a study was implemented in 1986/87 to collect and analyze productivity data on various manual stand improvement treatments. This report discusses the interim results of productivity studies conducted for "shortwood" merchantable thinning, shelterwood and remnant removal operations. Subsequent report(s) will detail the results of productivity studies for cleanings, stand conversions, and "tree length" merchantable thinnings and shelterwoods.

METHODS

TREATMENTS

At each of 15 study areas (Table 1) located throughout the province, blocks having similar site and stand conditions were identified. Each block was large enough to keep one worker busy for a minimum of two days. Major site and stand characteristics capable of affecting worker productivity were recorded (See Appendices 1 and 2). Post-treatment assessments were carried out to determine if treatment objectives were met.

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Table 1. Summary of the number of locations, blocks and average block size for each treatment.

Treatment*	Number of Locations	Number of Blocks	Average Block Size (ha)
Merchantable Thinning & Shelterwood (Shortwood)	9	19	.44
Remnant Removal	6	13	.36
•See Appendix 3 for definitions			

For merchantable thinning and shelterwood treatments (all in softwood stands), parallel extraction trails approximately 20 metres apart and 4 metres wide were cut prior to thinning the residual strips. Workers were required to pile the 8 foot wood (shortwood method) near the trails for forwarding. Since the same layout and work method was used in shelterwood and merchantable thinning operations, these treatments were combined for analysis. The productivity data for cutting extraction trails and thinning residual strips were recorded separately and then later combined. Future reports will discuss productivity for the individual operations. For remnant removal operations (shortwood method), a trail cutting operation was utilized where possible, but the scattered nature of the trees made this difficult in some situations. The operations were completed during the periods January and March, and May and July, 1987. Time studies related to the forwarding of merchantable wood were not carried out.

All operations were performed by 6 forestry instructors (4 regulars and 2 spares) from the Commercial Safety College in Masstown, Nova Scotia. In this way, variation due to worker productivity was minimized. Instructors were chosen on the basis of experience, observations of on-site performance, and an interview to determine motivation and attitude toward their work. The 4 regular workers had a minimum of 2 years experience, had previously worked on a production basis, and were familiar with the silvicultural treatments involved in the study. Two of the 4 chosen were forest technicians and all 6 had a strong forestry background and interest. At the Safety College, they were responsible for training students in the proper use and maintenance of chain saws with emphasis on felling techniques.

DATA COLLECTION AND ANALYSES

A work study technique called "work sampling" was utilized to determine the relative amount of time spent on productive and non-productive activities for each worker (Table 2). The advantages of using work sampling versus continuous time study include: reduced costs and training requirements, simpler data compilations, and increased

Table 2. Listing of measured productive and non-productive activities.

Productive Activities*	Non-Productive Activities*
Felling of Unmerchantable Trees	Breaks
Preparing to Fell	Lunch
Felling	Saw Maintenance
Freeing Hung-up Trees	Saw Repair
Limbing and Bucking	Other
Piling	
Moving	
Other	
*Definitions found in Appendix 4	

ability of the monitors to observe more than 1 worker or machine during the same time interval (Lussier 1961; Miyata 1981). This technique consists of taking instantaneous observations of a worker at given time intervals and noting which element of the work cycle (e.g. tree felling, limbing, bucking, etc.) is occurring. The number of observations for all productive tasks is multiplied by the total observation time and divided by the total number of observations to obtain productive man hours. The total observation time each day ranged from two to four hours per operator. Subsequent to "work sampling" the monitors scaled the wood produced by each operator. Sticks were scaled individually and the solid content was calculated using Smalian's formula (Husch, *et al.* 1972). Solid volumes (referred to as m^3 hereafter) were converted to stacked volumes (referred to as m^3 stk hereafter) by using a factor of 1.6 for softwood and 1.7 for hardwood. These factors were based on a comparison of individual stick and stack scales at various study sites. Finally, productivity in stacked cubic metres per productive man hour was calculated by dividing merchantable volume by productive man hours (pmh).

Stepwise linear regression and non-linear regression were used to relate production to various stand and site factors (Appendix 5). The results section discusses only the best regressions.

RESULTS AND DISCUSSION

PRODUCTIVE VERSUS NON-PRODUCTIVE TIME

Percent productivity did not vary greatly between the 2 treatments. Time spent on productive activities averaged 80% for merchantable thinning/ shelterwood operations and 81% for remnant removal operations.

MERCHANTABLE THINNING/SHELTERWOOD

From a graphical analyses (Figure 1.), productivity was found to be inversely related, in a non-linear fashion, to the number of trees per solid cubic metre (trees/m^3). Therefore, the following model was used in the regression analysis:

$$\text{Prod} = A\ (\text{trees}/m^3)^B$$

where,

Prod	= Productivity in m^3 stk/pmh
A,B	= Regression coefficients
trees/m^3	= Number of merchantable trees divided by merchantable volume

Figure 1 shows the resulting best-fitted regression equation based on this model ($r^2 = 0.56$, standard error of estimate = 0.59 m^3 stk/pmh). The

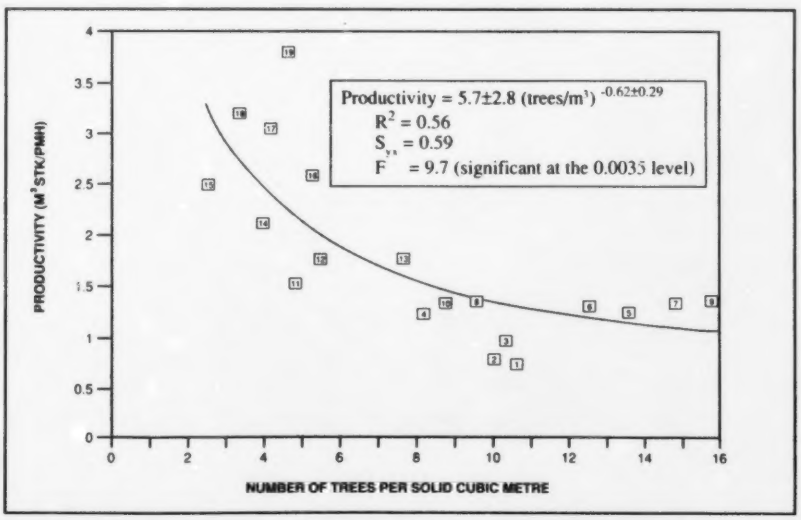

Figure 1. Productivity versus the number of trees per solid cubic metre for merchantable thinning and shelterwood operations. Detailed stand data found in Appendix 1; data points cross-referenced by block number. R^2 = adjusted coefficient of determination. Syx = standard error of the estimate. F = F value. ± = 95% confidence intervals for regression coefficients.

regression shows that worker productivity decreases dramatically as the number of trees per solid cubic metre increases to 7. For example, if the number of trees per solid cubic metre increases from approximately 2.5 to 7.0, worker productivity decreases from 3.2 to about 1.7 m^3 stacked per productive man hour; a decrease of 47%. After this point, the rate of decreasing productivity tends to level off. Between 7 and 11.5 trees/m^3, productivity decreases 24% from 1.7 to 1.3 m^3 stk/pmh. Appendix 6 shows predicted daily production values expected for various levels of trees per cubic metre based on the best fitted regression equation.

REMNANT REMOVAL

Unlike the merchantable thinning/shelterwood treatments, remnant removal productivity was found to be linearly related to merchantable volume per hectare and the number of trees per solid cubic metre (trees/m^3) (Figure 2). This relationship (R^2 = 0.68, standard error of estimate = 0.68 m^3/pmh) indicates that worker productivity increases as merchantable volume per hectare increases and stems per solid cubic metre decreases. According to this regression, for very low volume stands (e.g. 30 m^3/ha), productivity increases from 1.1 m^3 stacked/pmh for 18 trees/m^3 to 1.9 m^3 stk/pmh for trees/m^3. For high volume remnant removal operations (e.g. 60 m^3/ha), productivity can be expected to increase from 2.5 to 3.3 m^3 stk/pmh for the same trees/m^3 values. Appendix 7 lists the estimated daily production for various levels of merchantable volume and number of trees per cubic metre, based on the best fitted regression equation. It is noted that productivity is lower than expected because the silviculture worker was required to fell all unmerchantable trees on the site.

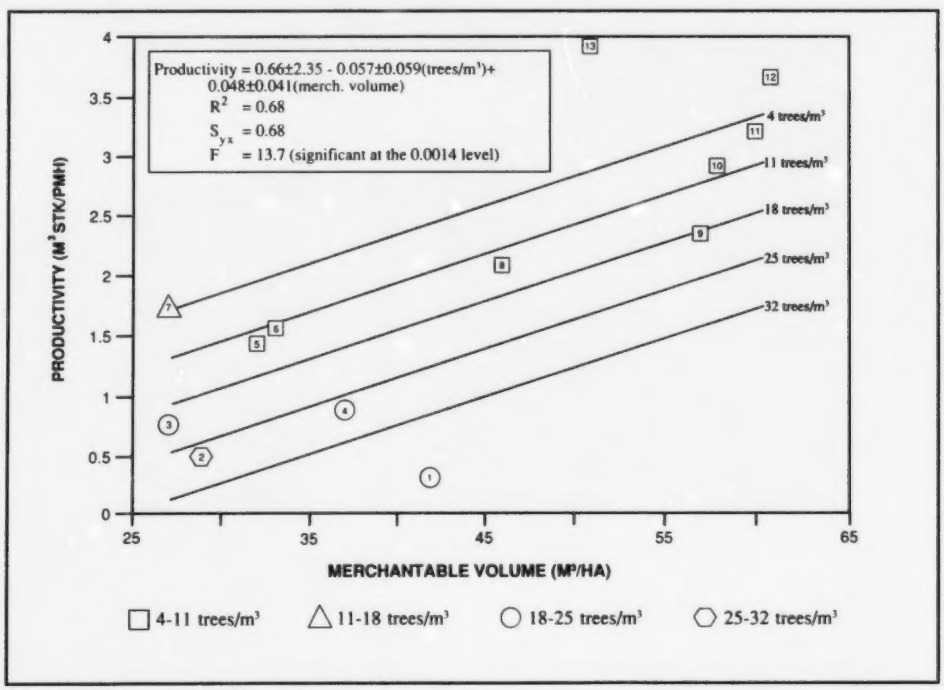

Figure 2. Productivity versus merchantable volume and the number of trees per solid cubic metre for remnant removal operations. Detailed stand data found in Appendix 2; data points cross-referenced by block number. R^2 = Adjusted coefficient of determination. S_{yx} = standard error of the estimate. F = F value. ± = 95% confidence intervals for regression coefficients.

SUMMARY

MERCHANTABLE THINNING/ SHELTERWOOD

The same layout and work method was used in both of these treatments, therefore the data were combined for analyses.

1. Worker productivity in cubic metres stacked per productive man hour (m^3 stk/pmh) was inversely related to trees per solid cubic metre (trees/m^3) in a curvilinear fashion according to the following regression equation,

Productivity = 5.7 (trees/m^3)$^{-0.62}$

2. According to the regression equation, production rapidly decreases as the number of trees per solid cubic metre increases from 1 to 7. For instance, production at 2.5 trees/m^3 is approximately double that at 7 trees/m^3 (3.2 versus 1.7 m^3 stk/pmh). As the number of trees per solid cubic metre increases above 7, production continues to decrease but at a reduced rate. Production decreases from 1.7 to about 1.3 m^3 stk/pmh between 7 and 11.5 trees/m^3.

REMNANT REMOVAL

1. Worker productivity (m^3 stk/pmh) was directly related to merchantable volume (m^3 solid/ha) and inversely to the number of trees per solid cubic metre (trees/m^3) according to the following regression equation,

Productivity = 0.66 - 0.057 (trees/m^3)
+ 0.048 (merch volume).

2. Productivity increases by approximately 70% (from 1.1 to 1.9 m^3 stk/pmh) for low volume stands (30 m^3/ha) and by about 30% (from 2.5 to 3.3 m^3 stk/pmh) for higher volume stands (60 m^3/ha) as trees per cubic metre decreases from 18 to 4.

APPENDICES

Appendix 1. Stand values for merchantable thinning and shelterwood operations.

Block #	Productivity m^3stk/pmh	Trees/m^3	Volume		Basal Area		Stand Density Stems/ha	Avg Height (m)	Avg Merch Dia (cm)	Stump age (years)	Regeneration		Limbiness (coded)*
			Merch m^3/ha	Total m^3/ha	Merch m^2/ha	Total m^2/ha					Density Stems/ha	Height (m)	
1	0.73	11	169	254	36	41	1797	12.4	16.0	62	1474	<1.5***	1
2	0.78	10	209	319	40	48	2096	13.4	15.6	63	1362	<1.5	1
3	0.95	10	247	387	53	62	2560	12.4	16.2	62	2956	3.8	1
4	1.23	8	194	314	38	47	1583	13.3	17.4	66	840	3.2	1
5	1.23	14	145	153	33	34	1962	11.9	14.6	63	355	<1.5	1
6	1.29	13	126	138	28	33	1577	11.9	15.1	63	1399	<1.5	1
7	1.31	15	165	283	42	52	2440	10.8	14.8	55	2129	3.0	1
8	1.34	10	211	312	41	47	2004	13.2	16.2	62	1550	4.6	1
9	1.34	16	128	208	31	37	2026	11.2	14.0	ND**	3580	<1.5	1
10	1.35	9	194	204	37	39	1678	13.4	16.8	63	747	<1.5	1
11	1.54	5	357	502	51	59	1698	17.0	19.5	80	620	6.0	1
12	1.76	5	286	382	42	46	1550	16.6	18.6	75	628	6.0	1
13	1.77	8	178	260	32	37	1350	14.0	17.5	ND	1249	<1.5	1
14	2.11	4	454	576	64	67	1781	17.2	21.4	86	319	<1.5	1
15	2.49	2	322	411	45	47	780	17.4	27.0	85	95	<1.5	1
16	2.60	5	313	510	42	57	1634	17.9	20.6	68	1244	6.2	1
17	3.03	4	270	359	38	41	1110	17.4	20.6	79	1041	<1.5	2
18	3.21	3	249	345	32	37	819	18.6	22.2	ND	1284	<1.5	ND
19	3.79	5	269	512	42	47	1235	15.7	20.7	81	979	1.5	2

* Limbiness Codes: 1 = ≤ 1/3 of stem with limbs, 2 = > 1/3 and < 2/3 of stem with limbs, 3 = ≥ 2/3 of stem with limbs
** ND = No Data
*** < 1.5 = Less than 1.5 metres in height

Appendix 2. Stand values for remnant removal shortwood operations.

Block #	Productivity m^3stk/pmh	Trees/m^3	Volume		Basal Area		Stand Density Stems/ha	Avg Height (m)	Avg Merch Dia (cm)	Stump age (years)	Regeneration		Limbiness (coded)*
			Merch m^3/ha	Total m^3/ha	Merch m^2/ha	Total m^2/ha					Density Stems/ha	Height (m)	
1	0.30	23	42	84	29	23	965	7.2	16.2	40	824	2.4	3
2	0.50	32	29	77	19	26	928	6.0	16.4	40	2116	2.2	3
3	0.76	26	27	51	13	15	701	7.0	15.6	40	560	2.4	3
4	0.88	21	37	82	18	23	763	7.0	17.6	40	1576	2.4	3
5	1.45	5	32	70	8	13	158	11.1	25.4	47	3800	1.5	3
6	1.59	8	33	133	9	26	268	10.3	20.7	45	7444	1.5	3
7	1.74	15	27	79	8	16	394	9.9	15.8	ND**	7340	3.6	1
8	2.08	7	46	110	13	22	303	10.1	23.4	52	5600	<1.5***	3
9	2.33	7	57	123	11	19	422	13.1	18.4	50	7805	2.3	1
10	2.89	6	58	109	13	18	322	12.2	20.2	92	624	1.5	1
11	3.19	7	60	109	16	20	151	10.8	22.3	ND	8250	2.9	1
12	3.64	9	61	147	16	28	151	10.6	19.0	ND	7475	<1.5	1
13	3.91	8	51	99	12	18	387	11.3	20.2	60	592	1.5	1

* Limbiness Codes: 1 = ≤ 1/3 of stem with limbs, 2 = > 1/3 and < 2/3 of stem with limbs, 3 = ≥ 2/3 of stem with limbs
** ND = No Data
*** < 1.5 = Less than 1.5 metres in height

Appendix 3. Descriptions of the silva cultural treatments included in the study.

Merchantable thinning and shelterwood - The data for the two treatments was combined because of similar layout, felling methods and eligibility qualifications. To be eligible for either treatment, stands must have at least 60% stocking and a minimum average merchantable diameter of 14 cm. The target basal area removal for both of the treatments was determined using the guidelines in the Nova Scotia Forestry Field Handbook (NSDLF, 1984).

Merchantable thinning is a spacing operation utilized to meet the following objectives:

1. increase productivity by harvesting trees that would otherwise be lost to mortality; and
2. promote the growth and quality of desirable crop trees.

A shelterwood treatment is a spacing operation to provide conditions conducive to the establishment and growth of natural regeneration.

Remnant removal is an operation that harvests trees in non-commercial stands having a merchantable average diameter of 14 cm or greater and a merchantable volume greater than 17.4 m^3 solid/ha (3 cds/ac) and less than 75 m^3 solid/ha (13 cds/ac). The purpose of the treatment is to salvage the merchantable trees and fell the unmerchantable trees, thereby creating conditions necessary for the establishment of a new and productive stand, either artificially and/or through natural regeneration.

Appendix 4. Definitions of the job activities listed in Table 2.

Productive Activities:

Felling of Unmerchantable Trees - The time to fell unmerchantable stems either in clumps or scattered throughout the stand.

Preparing to Fell - The time required to determine direction of fall and clear unmerchantable stems away from the crop tree.

Felling - The time from which the initial notch is started until the tree hits the ground or it becomes hung up.

Freeing Hung-up Trees - The time from when the tree becomes hung up until it is laying on the ground. Also included is any time required to get assistance for completely felling the tree.

Limbing and Bucking - The time to remove the branches and top plus cut the stem into pulp or logs. Includes moving brush to continue operation.

Piling - The time to pile 8 foot wood or logs for the forwarder or skidder. Also includes moving brush off the pile, etc.

Moving - The time spent moving during productive activities only.

Other - The time spent on productive activities other than those listed above. The activity(s) must be identified.

Non-Productive Activities:

Saw Maintenance - Time spent doing routine maintenance including gas, oil, saw filing, along with the time spent walking to and from the work area and maintenance location.

Breaks - Personnel breaks such as smoke breaks, etc. If the operator has a smoke at the same time as maintenance is being done, then the time is charged to maintenance.

Saw Repair - Time doing repairs other than routine maintenance. Includes time moving to carry out repairs.

Lunch - If the operator takes a formal lunch break, the duration is recorded in minutes.

Other - Time spent on non-productive activities not listed. These include supervision, looking for tools, etc. The specific activity(s) must be identified.

Appendix 5. Site and stand information collected for each location.

Site Characteristics
- History
- Exposure
- Topography
- Slope
- Soil Series
- Stoniness
- Site Impediments (cover)
- Drainage

Stand Characteristics (measured)
- Density (no. of trees)
- Height
- Diameter
- Crown Condition
- Limbiness
- Limb Diameter (class)
- Rot
- Age
- Regeneration Stocking
- Regeneration Density
- Regeneration Height
- Regeneration Distribution
- Regeneration Species

Stand Characteristics (calculated)
- Average Height
- Average Merchantable Diameter
- Total Basal Area
- Merchantable Basal Area
- Total Volume*
- Merchantable Volume*

*Based on NSLF, 1984

Appendix 6. Predicted daily production[1] in stacked cubic metres[2] versus the number of trees per solid cubic metre for merchantable thinning and shelterwood operations.

Trees/m³ (solid)	Daily Productivity (m³ stacked)
4	16.8
6	13.3
8	11.2
10	9.8
12	8.4
14	7.7
16	7.0

[1] A work-day is assumed to consist of seven productive hours per man (based on a 8.75 hour work-day and 80% productive time).
[2] To convert to cords multiply production figures by 0.276.

Appendix 7. Predicted daily production[1] in stacked cubic metres[2] versus trees per solid cubic metre and merchantable volume for remnant removal operations.

Merchantable Volume (m³ solid/ha)	Trees/m³ (solid)				
	4	8	12	16	20
30	13.1	11.5	9.9	8.3	6.7
35	14.8	13.2	11.6	10.0	8.4
40	16.4	14.8	13.3	11.7	10.1
45	18.1	16.5	14.9	13.3	11.7
50	19.8	18.2	16.6	15.0	13.4
55	21.5	19.9	18.3	16.7	15.1
60	23.2	21.6	20.0	18.4	16.8

[1] A work-day is assumed to consist of seven productive hours per man (based on a 8.6 hour work-day and 81% productive time).
[2] To convert to cords multiply production figures by 0.276.

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